PUSHOVER ANALYSIS OF RC FRAME STRUCTURE WITH FLOATING COLUMN AND SOFT STORY IN DIFFERENT EARTHQUAKE ZONES

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Abstract

Open first story and Floating column are typical features in the modern multi-storey constructions in urban India. Such features are highly undesirable in buildings built in seismically active areas; this has been verified in numerous experiences of strong shaking during the past earthquakes like Bhuj 2001. In this study an attempt is made to reveal the effects of floating column & soft story in different earthquake zones by seismic analysis. For this purpose Push over analysis is adopted because this analysis will yield performance level of building for design capacity (displacement) carried out up to failure, it helps determination of collapse load and ductility capacity of the structure. To achieve this objective, three RC bare frame structures with G+4, G+9, G+15 stories respectively will be analysed and compared the base force and displacement of RC bare frame structure with G+4, G+9, G+15 stories in different earthquake zones like Rajkot, Jamnagar and Bhuj using SAP 2000 14 analysis package.

***Keywords**: - floating column, soft story, pushover analysis, earthquake resistant structure.*

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1. INTRODUCTION

Many urban multistory buildings in India today have open first storey as an unavoidable feature. This is primarily being adopted to accommodate parking or reception lobbies in the first stories. The upper stories have brick unfilled wall panels. The draft Indian seismic code classifies a soft storey as one whose lateral stiffness is less than *50%* of the storey above or below [Draft IS: 1893, 1997]. For the upper storey's, however, the forces in the columns are effectively reduced due to the presence of the Buildings with abrupt changes in storey stiff nesses have uneven lateral force distribution along the height, which is likely to locally induce stress concentration. This has adverse effect on the performance of buildings during ground shaking. Such buildings are required to be analyzed by the dynamic analysis and designed carefully. Reinforced concrete (RC) frame buildings with masonry infill walls have been widely constructed for commercial, industrial and multi-family residential uses in seismic-prone regions worldwide. Masonry infill typically consists of brick, clay tile or concrete block walls, constructed between columns and beams of a RC frame. These panels are generally not considered in the design process and treated as architectural (non-structural) components On the other hand, negative effects can be caused by irregular positioning of the infill's in plan.

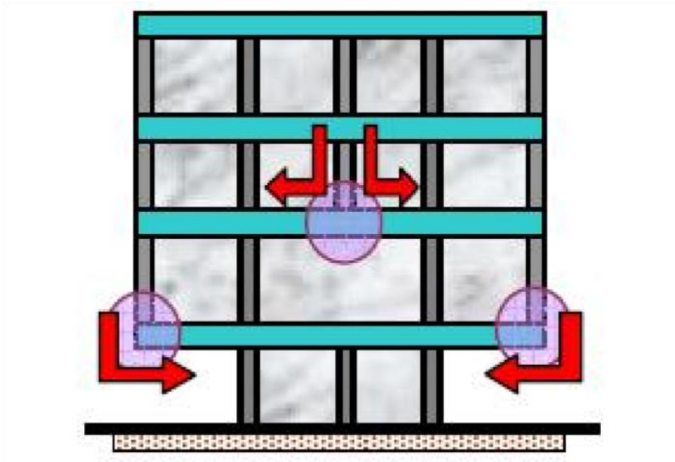


Fig 1: Floating Columns

2. LITERATURE REVIEW

The literature review showed there is a lack of information Regarding pushover analysis and different seismic parameters over the building.

The general features of a few selected researches are shown below regarding pushover analysis of RC soft story structure and seismic analysis of floating column structures.

2.1 Seismic Response of Complex Buildings with Floating Column for Zone II and Zone V. [1]

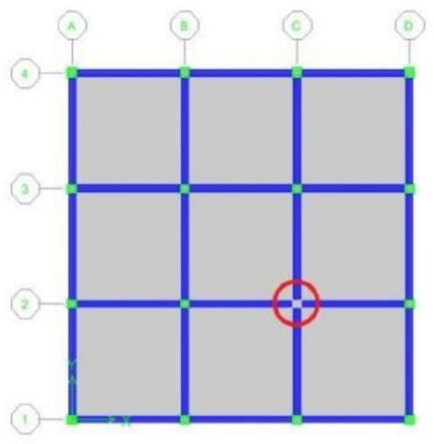
The entire work consists of four models (Model FC, Model FC+4, Model FC+HL, Model FC+4+HL). And these models were modeled and analysed for lower (II) and higher (V) seismic zones for medium soil condition. The results are tabulated for base shear, story drift and lateral displacements. The model having only floating column, the model having a floating column by increasing the height of the storey, the model having a floating column by heavy load on the slab where floating column is provided, and a last model in which floating column is provided by rising the storey height a heavy load on slab, these four models were analysed by changing the location of floating column firstly in the middle, outer and in edge of the frame of building. The plans of the models are shown in figs 1, 2, 3. The models considered the present study are:

Model FC: Where **only Floating Column** is provided in a particular location, particular floor and in a particular zone.

Model FC+4: **Where Floating Column** is provided by **rising the Story Height by 4 m** in a particular location, particular floor and in a particular zone.

Model FC+HL: Where **Floating Column** is provided by applying **Heavy Load** on the slab, particular floor and in a particular zone. (Heavy load may be swimming pool, water tank or machinery room etc...)

Model FC+4+HL: Where **Floating Column** is provided by **rising the Story Height by 4 m** along with provision of **Heavy Load** in a particular location, particular floor and in a particular zone.



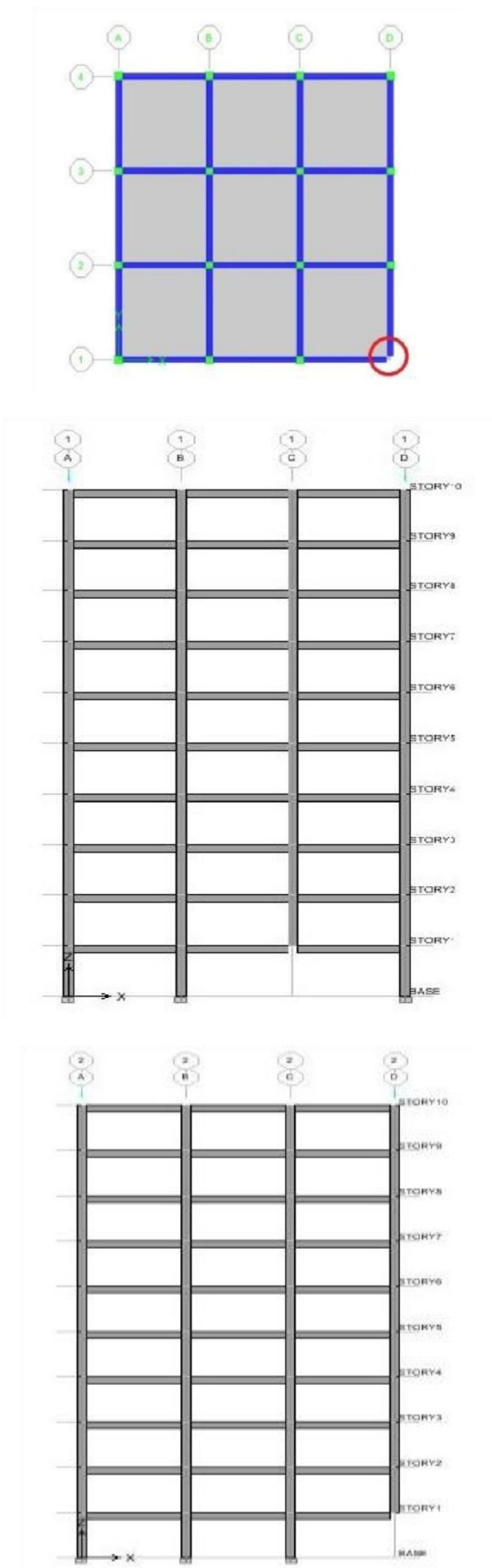


Fig 2: Position of Floating Column in Building

2.1.1 Methodology

The present study is done by using ETABS 9.7.4. It is a fully integrated program that allows model creation, modification, execution of analysis, design optimization, and results review from within a single interface. ETABS9.7.4 is a standalone finite element based structural program for the analysis and design of civil structures. It offers an intuitive, yet powerful user interface with many tools to aid in quick and accurate construction of the models, along with sophisticated technique needed to do more complex projects.

Table 1: Building Data

PARAMETERS	Model FC	Model FC+4	Model FC+HL	FC+4+HL
Soil Type	Medium soil (II)	Medium soil (II)	Medium soil (II)	Medium soil (II)
Seismic Zone	II and V	II and V	II and V	II and V
Response Reduction Factor	5	5	5	5
Importance factor	1	1	1	5
Height of Building	30 m	31 m	30 m	31 m
Floor Height	3 m	3 m and 4m	3 m	3 m and 4 m
Thickness of Slab	150 mm	150 mm	150 mm	150 mm
Beam Size	300X450 mm	300X450 mm	300X450 mm	300X450 mm
Column Size	450X450 mm	450X450 mm	450X450 mm	450X450 mm
Slab Thickness	150mm	150mm	150mm	150mm
Live Load	3.5 KN/m2	3.5 KN/m2	3.5 KN/m2	3.5 KN/m2
Heavy live load	-	-	10 KN/m2	10 KN/m2
Floor Finish	1 KN/m2	1 KN/m2	1 KN/m2	1 KN/m2
Heavy Dead load	-	-	10 KN/m2	10 KN/m2
Spacing of columns	5 m c/c	5 m c/c	5 m c/c	5 m c/c
Support condition	Rigid	Rigid	Rigid	Rigid
Material Properties	M25 Grade of Concrete	M25 Grade of Concrete	M25 Grade of Concrete	M25 Grade of Concrete

2.1.2 Results and Discussion

The present study is to compare, how the behavior of a building having only floating column and having a floating column with complexities. The floating column locations are also varied to find the optimum position. For zone II and V, live load and dead loads were varied for heavy load condition. Analysis is carried out for various complex systems and the results are presented in the form of tables and figures and are discussed in the present chapter. The results are obtained in terms of Displacements, Storey shear, Storey drifts, for different parameters varied.

Floating column is provided in the middle of the ground floor.

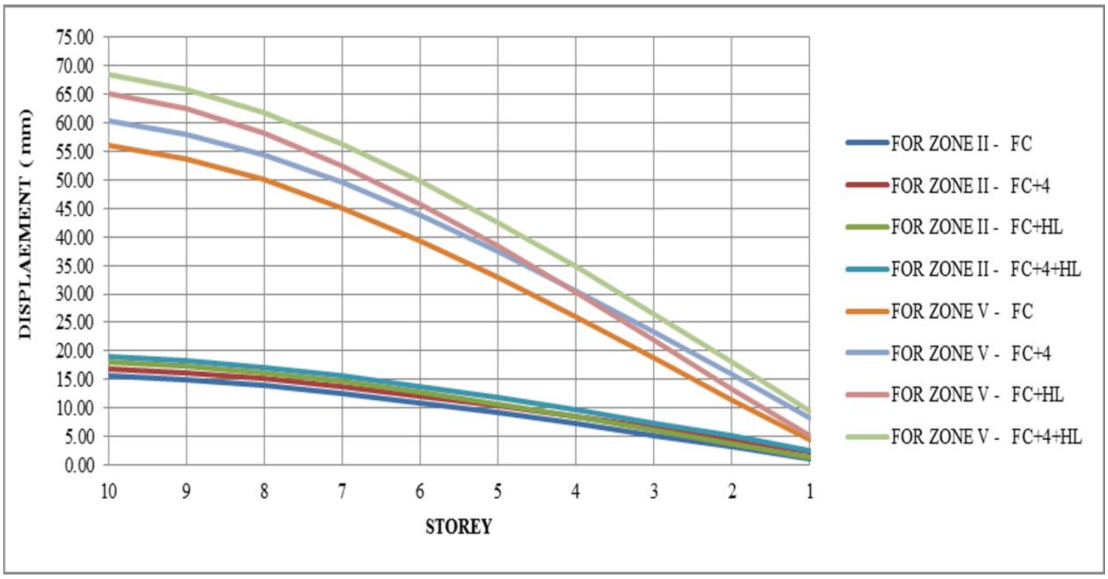


Fig 3 : Comparison of Lateral Displacements.

Floating column is provided in the middle of eight floor

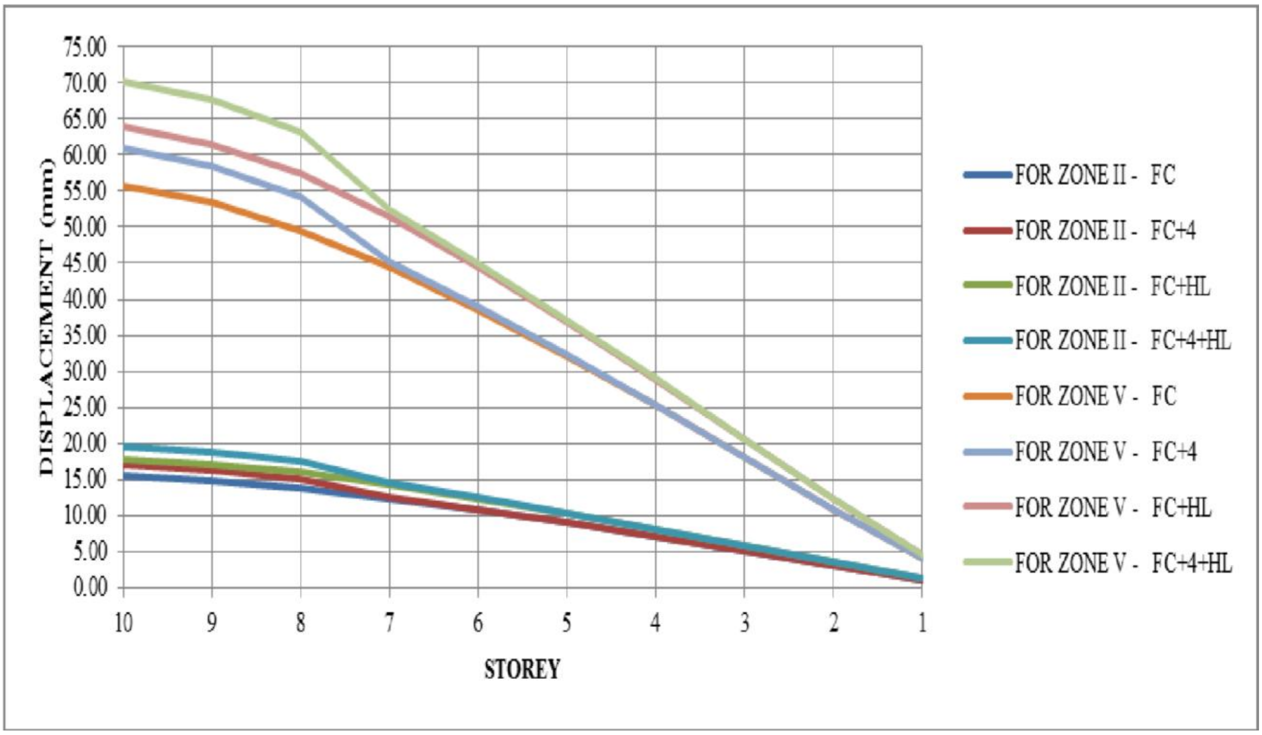


Fig 4: Comparison of Lateral Displacement

2.2 Effect of Soft Story on Tall Buildings at Various Stories by Pushover Analysis. [2]

India at present is fast growing economy, which brings about demands in increase of infrastructure facilities along with the growth of population. The demand of land in urban regions is increasing day by day. It is imperative that land available for farming and agriculture remains intact. To cater the land demand in these regions, vertical development is the only option. This demands changes in the current structural system which needs to be implemented to resist these forces. Much research has been carried which describes the suitability of various lateral load resisting system against deformation and shear exerted due to the earthquake.

Soft story irregularity is one of the main reasons of building damages during recent earthquakes in the world as mentioned in almost all reconnaissance reports and studies soft story may arise not only because of sudden changes in the structural system (like the height of the stories) but also due to abrupt changes in amount of infill walls between stories which are usually not considered as a part of the load bearing system.

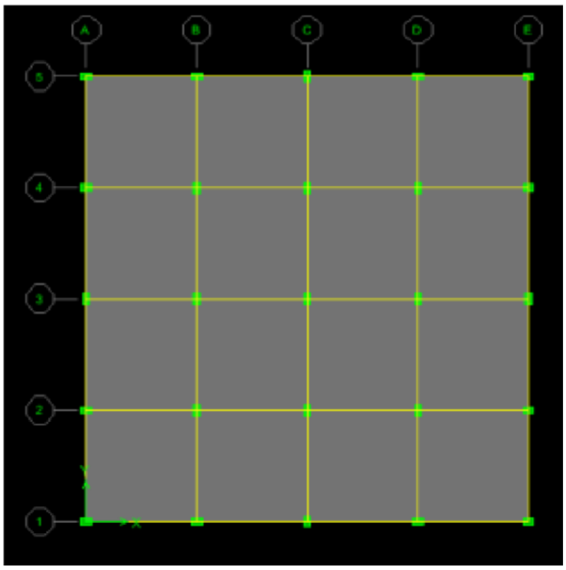
2.2.1 Modeling of the Building

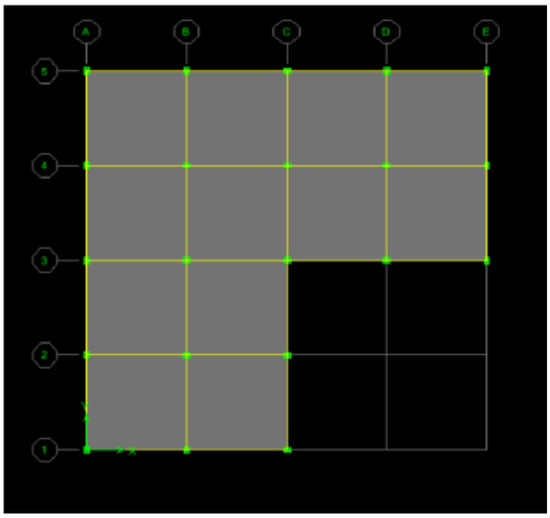
The entire analysis has done for all the 3D models using ETABS Nonlinear version software. The results are tabulated in order to focus the parameters such as base shear, story drift and lateral displacements in linear analysis.

Regular Building: it is modeled with symmetrical plan and elevation in three different heights, i.e 5, 10 and 15 stories, shown in fig below.

L-Shaped Building: it's a plan irregular building, as shown in fig, modeled for 5, 10, and 15 stories.

T-Shaped Building: it's a plan irregular building, as shown in fig, modeled for 5, 10, and 15 stories.





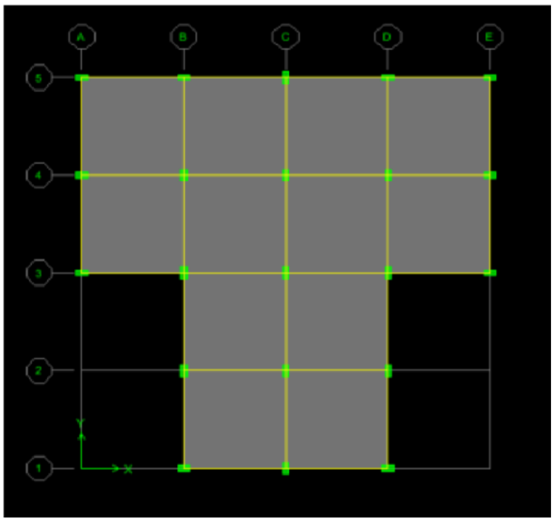


Fig 5: Different Shapes Of Building

2.2.2 Methodology

The software used for the present study is ETABS 9.7.4. It is product of Computers and Structures, Berkeley, USA. ETABS9.7.4 is used for analyzing general structures including bridges, stadiums, towers, industrial plants, offshore structures, buildings, dam, silos, etc. It is a fully integrated program that allows model creation, modification, execution of analysis, design optimization, and results review from within a single interface. ETABS 9.7.4 is a standalone finite element based structural program for analysis and design of civil structures.

The analysis is carried out by both linear static and nonlinear static methods in accordance with IS-1893-2002 (part-1), to study the performance levels and performance points of the building. Building data used for modeling all kinds of the buildings are tabulated below:

Table 2: Building Data Used For Modeling.

PARAMETERS	**5 storey**	**10 storey**	**15 storey**
Seismic Zone	V	V	V
Seismic Zone	0.36	0.36	0.36
Factor			
Response Reduction Factor	5	5	5
Height of Building	16 m	31 m	46 m
Thickness of infill Wall	0.23 m	0.23 m	0.23 m
Thickness of Slab	0.120 m	0.120 m	0.120 m
Beam Size	0.25 X 0.35 m2	0.3 X 0.4 m2	0.3 X 0.45 m2
Column Size	0.25 X 0.35 m2	0.3 X 0.5 m2	0.3 X 0.6 m2
Live Load	3 kN/m2	3 kN/m2	3 kN/m2
Floor Finish	1 kN/m2	1 kN/m2	1 kN/m2
Material Properties	M25 Grade of Concrete	M25 Grade of Concrete	M25 Grade of Concrete

2.2.3 Results and Discussion

In the present study, non-linear response of RC frame high rise building with soft storey at different levels in addition to one at ground floor using ETABS under the loading has been carried out. The objective of this study is to see the variation of load- displacement graph and check the maximum base shear and displacement of the frame with soft stories at different levels. Following are the graphs drawn for the regular 15 storey building using linear static analysis.

Lateral displacement of 15 storey regular building

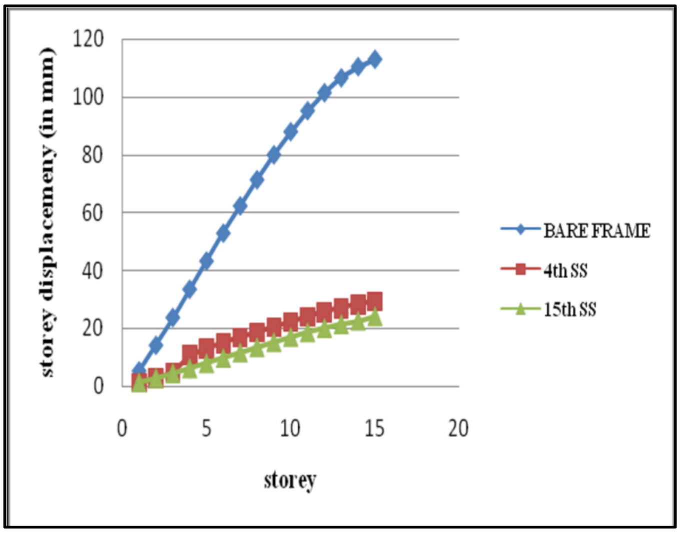


Fig 6: Comparison of lateral displacement of bare frame with maximum and minimum top storey displacements.

Table 3: lateral displacement of plan and vertical irregular buildings of 5, 10 and 15 storied buildings

DISPLACEMENT (mm)			
BUILDING TYPE	**BARE FRAME**	**MAX**	**MIN**
L-5 STOREY	41.813	6.3454	3.2868
L-10 STOREY	51.392	12.684	8.765
L-15 STOREY	108.744	29.533	24.035
T-5 STOREY	44.491	6.1943	3.5372
T-10 STOREY	59.4166	13.1184	9.123
T-15 STOREY	111.639	29.2145	23.8701

2.3 Seismic Assessment of an RC Building Using Pushover Analysis. [3]

An RC building using Push over analysis method. This study aims to investigate building performance on resisting expected seismic loadings. Two 3D frames were investigated using pushover analysis according to ATC-40. One was designed according to a design practice that considers only the gravity load and the other frame was designed according to the Saudi Building Code (SBC-301).

The building performance level can be determined by target displacement using the capacity spectrum method (ATC 40). The capacity spectrum method allows for a graphical comparison between the structure capacity and the seismic demand. The pushover curve represents the lateral resisting capacity and the response spectrum curve represents the seismic demand.So, up to 30% replacement of cement by ceramic waste slurry powder is technically and economically feasible and viable.

Pushover Analysis requires the development of the forced deformation curve for the critical section of beams and column by using the guideline in. Such a curve is presented in Figure

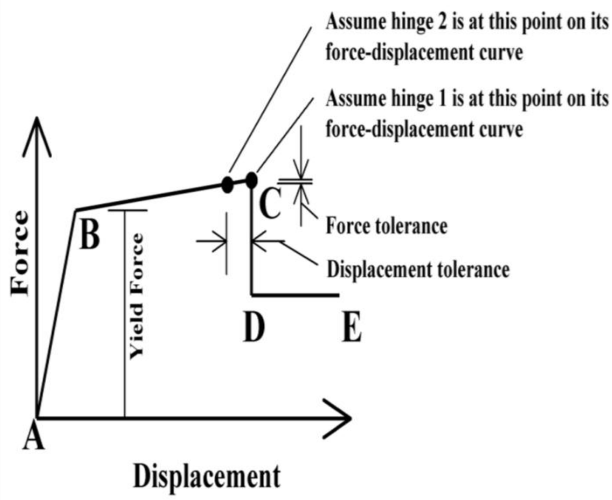


Fig 7: Typical Load Deformation Curve

Point A corresponds to the unloaded condition. Load deformation relation shall be described by the linear response from A to an effective yield B. Then the stiffness reduces from point B to C. Point C has a resistance equal to the nominal strength then a sudden decrease in lateral load resistance to point D, the response at reduced resistance to E, final loss of resistance.

The slope of the BC line is usually taken between 0 and 10% of the initial slope. The CD line corresponds to an initial failure of the member. The DE Line represents the residual strength of the member. These points are specified according to FEMA to determine hinge rotation behavior of RC members.

The prototype building is a 6-story reinforced concrete structure, with a height story of 4.0 m. The overall plan is 18x18 square meters. Figure 3 shows the typical structural layout. All beams are 600/400. The columns are 500/500 mm rectangular. The type of soil is soft rock or site class C according to the Saudi Building Code 301.

Table 4: Assumptions of the Model

Material	
Concrete	27.5 MPa
Steel	A615Gr60
Loading	
Self-weight	Automatically by Software
Dead load	2.7 kN/m^2
Live load	2.5 kN/m^2
Wind load	Not considered
Modelling	
Element	Linear element by beam and column Shell element for slab
P-delta effect	Not considered
diaphragm	Shell element for slab
Support	Fixed

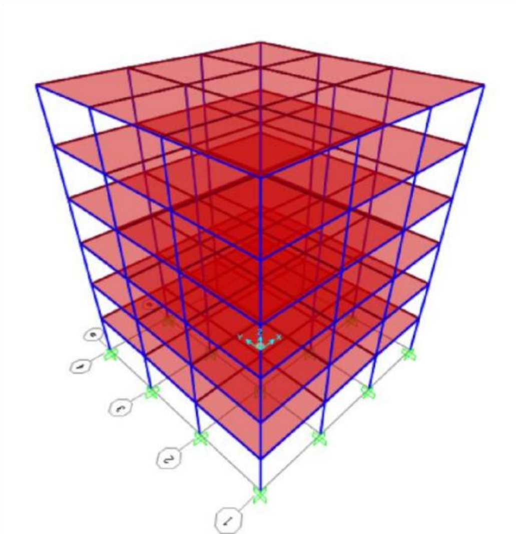


Fig 8: 3D Model in SAP2000

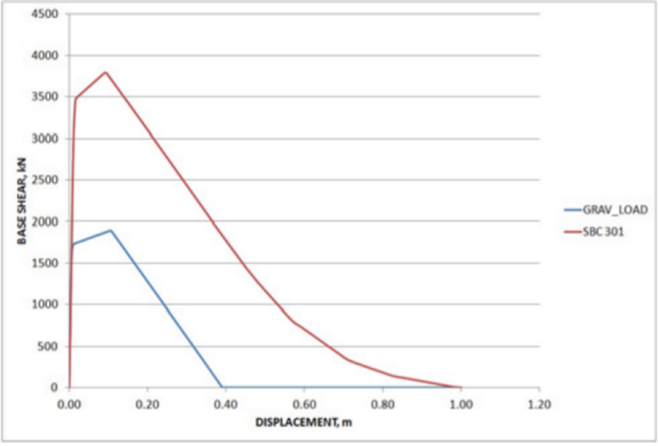


Fig 9: Pushover Curve

Pushover analysis can identify weak elements by predicting the failure mechanism and account for the redistribution of forces during progressive yielding. It may help engineers take action for rehabilitation work. The results show that design considering only gravity load is found inadequate. Therefore, a structural engineer should consider earthquakes in designing building.

3. CONCLUSION

- From the above research papers, Conclusion are made that up various methods of the nonlinear static analysis are studied out of which push over analysis is the accurate and efficient method of analysis yet some parameters are yet to be evaluated in it.
- Base shear increases with the increase of mass and number of story of the building, also base shear obtained from pushover analysis is much more than the base shear obtained from the equivalent static analysis.
- The displacement of building increases from lower zones to higher zones, because the magnitude of intensity will be more for higher zones, similarly for drift, because it is correlated with the displacement.
- Whether the floating columns on ground floor or in eight floors the displacement values increases when a floating column is provided in edge and middle than the outer face of the frame.
- In all models the displacement values are less for lower zones and it goes on increases for higher zones.

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